SULFUR INFLUENCE ON CORN AND SOYBEAN YIELDS IN EASTERN SOUTH DAKOTA

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Abstract

Clean air legislation, the increasing use of conservation tillage, and the manufacture of phosphorus fertilizers without sulfur have all contributed to lowering soil sulfur (S) availability to crops. Soil S availability has been affected to some extent by all three issues in eastern South Dakota. Hilltop erosion has exposed subsoil in which the pH is higher and organic matter content is lower than at lower landscape positions. In some eroded shoulder positions of the landscape in no-till fields, corn (*Zea mays* L.) yields are depressed relative to yields in footslope positions. Leaf striping (interveinal chlorosis) in corn was observed indicating a possible S deficiency. Experiments established in farmer's fields in eastern South Dakota from 1990-2001 measured corn and soybean grain yield responses to applied S in no-till and conventional tillage systems. Only eight of the 71 corn site-years were responsive to an S application of 25-30 lbs./a with a mean grain yield increase of 22.4 bu/a for the responsive sites. The extractable sulfate-sulfur (0-2') on responsive sites was at or below 40 lbs. S/a in most of the sites and organic matter levels were 2.6% or less. When S applications were applied to a no-till landscape toposequence in the southeast corner of South Dakota, S applications increased grain yields on the most eroded landscape positions. Soybean (*Glycine max* L.) yields increased only on three of the 32 experimental site-years. The mean yield increase on the responsive sites was only 2.2 bu/a. These responses indicated that sulfur deficiencies in corn and soybeans were not widespread in eastern South Dakota but may be more of an issue with corn than soybean production.

Introduction

In the past 25 years, tillage management and environmental issues lowered sulfur availability in soils. The Clean Air and Water Acts of the 1970's have reduced sulfur dioxide emissions to the atmosphere and subsequently reduced sulfur (S) levels in precipitation for which growing crops could have utilized. In some locations downwind from power plants, the contribution was substantial. Secondly, the implementation of conservation tillage (minimum till and no-till), reduced crop residue decomposition in soils. Less soil disturbance reduced the S release from organic matter that could be recycled to growing crops. Thirdly, the fertilizer industry now manufactures a single P nutrient dry fertilizer, triple super phosphate (0-46-0), which is the product of rock phosphate processed with phosphoric acid. This has replaced processing the rock phosphate with sulfuric acid which was the prevailing manufacturing process in the 1940's - 1960's and eliminated S from the single-nutrient dry P fertilizer material. In South Dakota, soil sulfur availability has been affected to some extent by all three issues.

Tillage has exposed the glacial till, outwash gravel, or loess parent materials on some slopes in eastern South Dakota. Soil organic matter (O.M.) content is lower and soil pH is often higher on these eroded sites compared to the footslope position (depositional site with no erosion). Grain yields of corn and soybeans growing on these eroded sites are depressed. A number of soil physical, chemical, and nutrient factors contribute to this. Corn leaf striping (interveinal chlorosis) was observed on the shoulder (severe erosion) and backslope (moderate erosion) landscape positions over the past several years in eastern South Dakota. Historically, a similar leaf coloration pattern has been attributed to micronutrient metal (Fe or Mn) deficiencies although it is not as distinct. However, S fertilizer applications ameliorated some of the leaf striping and increased grain yield to some extent. The need for supplemental S in these eroded areas was indicated. It is suspected that insufficient levels of available SO_4-S on eroded positions of no-till fields are related to lower decomposition of organic matter already reduced by erosion.

Sulfur deficient soybean plants generally do not exhibit symptoms as obvious as the striking striping pattern in corn. However, since S is a critical component of amino acid and oil formation, soybean yields may be limited by S when cropped on these eroded slopes. It was important to investigate to what extent that sulfur deficiencies exist in corn and soybean in eastern South Dakota. It was also necessary to determine whether grain yield responses to S fertilizer applications can be predicted by traditional soil testing methodology.

Methods and Materials

Seventy-one corn sites and 32 soybean sites were established in farmer's fields in Brookings, Clay, Deuel, Faulk, Hutchinson, Kingsbury, Lake, McCook, Minnehaha, and Spink counties from 1990-2001 to measure S fertilizer responses. About half of the field sites were tilled and the other half were in no-till. Soils cores were removed from treatment plots to determine organic matter (O.M.) and sulfate-S. Soil sulfate-S was determined by the turbidimetric method after a Ca-phosphate extraction. Organic matter was determined by Loss on Ignition (LOI). Treatment plots of varying sizes were established in each field. Each S fertilizer treatment pair (25-30 lbs./a sulfur fertilizer vs. a S control) was randomized and replicated four times. Sulfur was applied as ammonium sulfate as a post-planting broadcast treatment or as a liquid ammonium thiosulfate banded as a starter treatment at planting.

Landscape position was included as an additional factor at a few of the site-years in the southeast part of the state. The paired sulfur treatment sets were established on the shoulder, backslope, and footslope position for corn. The mollic depth at these landscape positions was approximately 4-6", 7-12", and >20" respectively. Soybeans were planted on the shoulder and footslope positions.

Corn was planted at a standard plant population (25-28,000 plants/a) usually in 30" rows with an adapted (90-105 day) hybrid. Herbicides and other fertilizers were applied as required to obtain reasonable yield goals. Plant tissue samples were taken at either an early (6 leaf stage) and/or late (ear leaf at silking) stage of growth to determine dry weight and S concentration. Cobs were harvested manually at physiological maturity, shelled, and yields were estimated after adjusting for moisture content. Soybeans were usually planted either in 7" or 30" rows with an adapted (Group I or II) variety. Plant tissue was sampled at the early bloom stage of growth to determine dry weight and S concentration. Grain was harvested by a small plot combine at physiological maturity and yields were estimated after adjusting for moisture content. The soil, plant tissue, and grain data was analyzed statistically with SAS.

Results and Discussion

General Corn Responses

Sulfur applications increased corn grain yields significantly in only 8 of the 71 sites compared to untreated plots (Table 1). The mean increase of the significant responses was 22.4 bu/a, which was substantial and also economical. Mean extractable soil sulfate-sulfur (0-2' depth) in the significant sites was 30 lbs./a, which is considered 'high' for current recommendations.

Table 1. Mean site-years where the corn grain yield after the S fertilizer application was significantly greater than the control treatment (without S fertilizer) for 1990-2001.

	Significant Sites			
Total	Number	Mean Yield Increase	Mean Soil Sulfate-S (0-24")	Mean Soil O.M.(0-6")
		- bu/a -	- lbs./a -	- % -
71	8	22.4	30	2.6

Plotting relative yield responses of all the site-years indicated that the soil extractable sulfate-S levels (turbidimetric method) all eight responsive site-years were at or below a mean extractable sulfate-S level of about 40 lbs. S/a (Fig. 1). Only two of these sites were in conventional tillage. The 40 lbs. S/a level is considered 'very high' by current soil testing methodology and revising the soil test critical level especially for no-till production should be considered. However, there were 32 non-responsive site-years for which the soil test S level is at or below the 40 lbs. S/a level. These sites did not respond to fertilizer S applications. It is possible that these crops obtained their S requirements from the dissolution of native S minerals (probably gypsum and epsomite) not recognized by the soil test, or from the presence of sulfate deeper than the 0-2' sample depth. Routine soil testing of these fields may always lead to overestimation of the S needs of a crop, but there may not be a simple solution to the problem until the source of this prediction inconsistency is identified.

The mean organic matter level for responsive site-years was 2.6% (Table 1). This is higher than the 2% 'rule of thumb' some consider to be adequate and would not require an S fertilizer application to obtain a reasonable grain yield. Perhaps in no-till fields, a higher organic matter level may be required to mineralize the same level of soil S mineralized in tilled fields in order to meet crop S needs. The probability of an S fertilizer response may increase below this threshold level There are a few fields in eastern South Dakota which have overall organic matter levels below this level but for the most part they are limited to eroded sites.

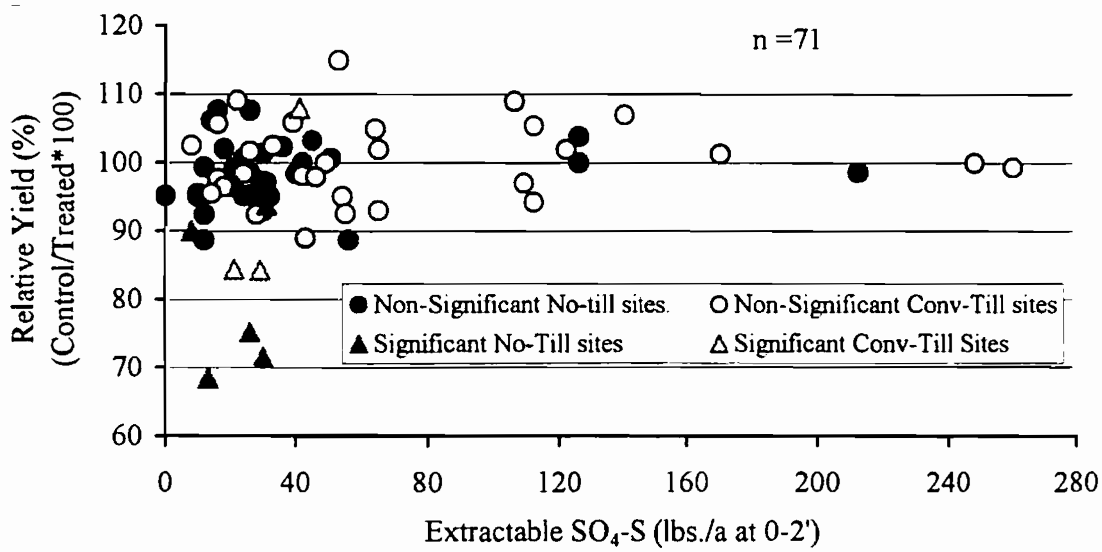

Figure 1. Mean relative corn yield responses to S applications for all site-years in eastern South Dakota in 1990-2001.

Corn Responses on a Toposequence

A 30 lbs. S/a fertilizer application increased S concentration in the ear leaf of corn growing at the shoulder and backslope positions (Table 2). Applications of S fertilizer increased overall mean grain yield by 12.2 bu/a at the shoulder position and 11.5 bu/a at the backslope position. Overall mean yields on the footslope position was the greatest (165-166 bu/a) but there was no yield response after an S application at this position. The deep mollic horizon provided many favorable chemical and physical properties (higher water holding capacity, root penetration potential, C.E.C., and O.M. mineralization) that contributed to an optimum yield potential. Despite the increase in grain yields after S applications on the shoulder position, the mean yields were still 30+ bu/a lower than the mean yields at the footslope. This indicated that other factors besides S were limiting yields on these eroded slopes.

Table 2. The LSD for mean corn response parameters comparing S fertilizer treatments within landscape positions in 1999-2001 at Garretson, SD.

	Response Parameter			
Landscape Position	V6 Dry Weight	V6 S Uptake	Ear Leaf S Concentration	Grain Yield
Shoulder	g	lbs/a	%	bu/a
Control (0 lbs. S/a)	33.9	0.79	0.138 a	121.9
Sulfur (30 lbs. S/a)	33.8	0.75	0.171 b	134.1
LSD.10	NS	NS	0.019	NS
Backslope				
Control (0 lbs. S/a)	42.5	0.92	0.154 a	140.4 a
Sulfur (30 lbs. S/a)	42.0	0.90	0.173 b	151.9 b
LSD.10	NS	NS	0.019	10.6
Footslope				
Control (0 lbs. S/a)	45.5	1.01	0.180	165.8
Sulfur (30 lbs. S/a)	44.3	0.94	0.190	166.8
LSD.10	NS	NS	NS	NS

General Soybean Responses

Fertilizer S applications increased grain yields significantly in only 3 of the 32 soybean site-years compared to the control plots (Table 3). The mean increase of the significant responses was 2.5 bu/a, which was probably not economical. Mean sulfate sulfur (0-2' depth) levels (turbidimetric method) of the significant site-year means was 28 lbs./a which is considered 'medium'. The mean organic matter level for these site-years was 2.2%. Although there were not as many site-years as in corn, it is notable to observe that all of the responsive sites were in no-till production and occurred in the southeast part of the state.

Table 3. Mean site-years where the soybean grain yield after the S fertilizer application was significantly greater than the control treatment (without S fertilizer) for 1990-2001.

	Significant Sites			
Total	Number	Mean Yield Increase	Mean Soil Sulfate-S (0-24")	Mean Soil O.M.(0-6")
		- bu/a -	- lbs./a -	- % -
32	3	2.5	28	2.2

Plotting relative yield responses of the 32 site-years indicated that the soil extractable sulfate-S levels of three site-years were at or below a mean extractable sulfate-S level of about 35 lbs./a (Fig. 2). This is considered 'high'. These critical levels for S sufficiency were developed with data developed for mostly conventionally tilled sites. Mineralization in these sites was probably greater than sites under conservation tillage. So soybeans under no-till production would probably require a higher critical O.M. level to make up for the S that would have been mineralized and available under conventional tillage. However, there were 17 non-responsive no-till sites in which the soil sulfate levels was below 35 lbs./a. For these sites, the soil test S levels were similar to those of the responsive sites. However, these crops did not respond to S applications. Similarly to the 32 non-responsive low soil S corn site-years (Fig. 1), soybeans growing at these sites may be tapping into an S source that was not measured by current soil test methodology.

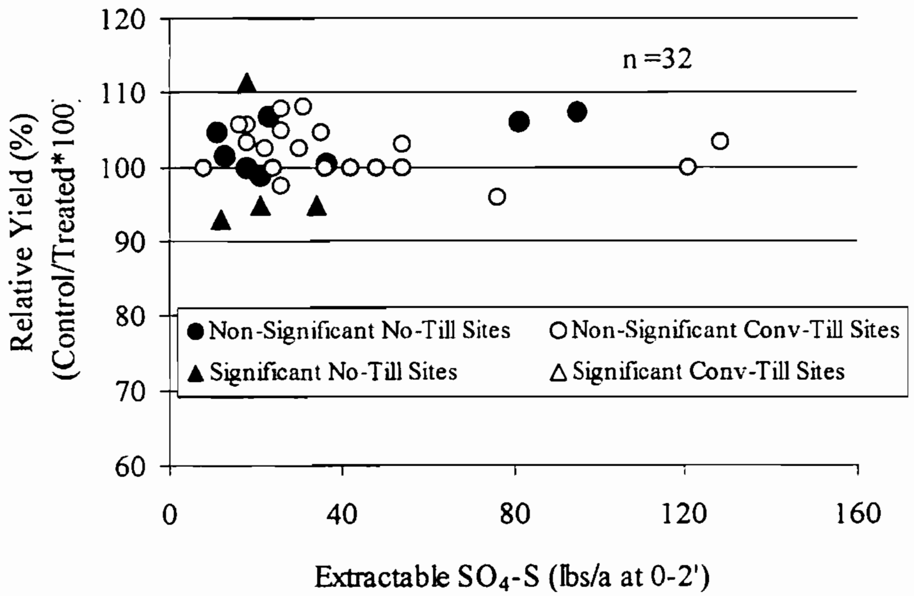

Figure 2. Mean relative soybean yield responses to S applications for all site-years in eastern South Dakota in 1990-2001.

Soybean Responses on a Toposequence

Soybeans planted at either a shoulder or footslope position did not respond to additional fertilizer S applications. Grain yield did not increase on the shoulder position of the landscape after a S application where available S is typically lower despite the increase in early bloom shoot S uptake (Table 4). Yield responsiveness at these sites was more in line with the results of the more inclusive soybean study in Table 3 and Fig. 2 than the high responsiveness of corn yields to S applications observed in this region of the state.

Table 4. The LSD for mean soybean response parameters comparing S fertilizer treatments within landscape positions in 1999-2001 at Garretson, SD.

	Response Parameter		
Landscape Position	Early Bloom Dry Weight	Early Bloom S Uptake	Grain Yield
Shoulder	g	lbs/a	bu/a
Control (0 lbs. S /a)	106.8	1.69	40.8
Sulfur (30 lbs. S /a)	94.6	1.86	40.1
LSD.10	NS	NS	NS
Footslope			
Control (0 lbs. S /a)	123.5	2.06	48.6
Sulfur (30 lbs. S /a)	107.3	2.08	47.6
LSD.10	NS	NS	NS

Conclusions

Despite the environmental and management issues that would indicate a need for greater S fertilization to crops, corn and soybean grain yield responses to S applications are not common in eastern South Dakota. Responses generally occurred where the extractable sulfate (0-2' depth) was < 40 lbs./a and the organic matter was less than 2.6%. However, there are some locations in southeastern South Dakota where corn grain responses were more predictable. Utilizing a soil sulfate extraction test (0-2') is the best method of identifying these locations. However, there is a possibility that the soil S availability may be underestimated elsewhere because of the possible contribution of mineral S forms not detected with standard soil test methodology and presence of soil sulfate deeper than the standard 0-2' sampling depth.

Acknowledgement

This research was supported in part by the South Dakota Corn Utilization Council, the Soybean Research and Promotion Council, and the Fluid Fertilizer Foundation. We also appreciate the lab support we received from the South Dakota State University Soil and Plant Analysis Laboratory, Belmond Lab of Belmond, IA, and Olsen Agricultural Lab of McCook, NE.

PROCEEDINGS OF THE

THIRTY-SECOND NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 18

November 20-21, 2002
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Des Moines, IA

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Published by:
Potash & Phosphate Institute
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Brookings, SD 57006
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Web page: www.ppi-ppic.org